SEMICONDUCTOR LASER DIODE WITH A DISTRIBUTED REFLECTOR

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Laser devices are commonly used as light sources, and it is of particular interest to be able to obtain laser sources which have high quality spectral performance for data communication applications. It is of particular interest to be able to manufacture such devices in a relatively simple and low cost way, to achieve a robust device. In particular it is advantageous to achieve a device with a highly selective optical spectrum, that is, a device which produces a large amplitude peak at one specific wavelength of output light.

One type of laser device which can be used as such a source is a Distributed Feedback (DFB) laser, and the related Distributed Bragg Reflector (DBR) laser. However, conventional techniques for manufacturing such devices include regrowth steps, which make the manufacturing relatively expensive.

The paper "1.5μm wavelength DBR lasers consisting of $3\lambda/4$-semiconductor and $3\lambda/4$-groove buried with benzocyclobutene", M.M.Raj, J. Wiedmann, Y. Saka, H. Yasumoto and S. Arai. *Electronics Letter, Vol.. 35, No. 16, pp. 1335-1337* describes a method of manufacturing deep etched (DBR) lasers. Since this technique involves etching into and across the active layer, the wave ceases to be guided within the etch, which means that these devices are likely to be inherently lossy.

The present invention relates to a laser device, with a ridge waveguide, with a distributed reflector on either side of the central ridge.

Since the light wave remains guided, this has the advantage that the device is relatively efficient.

Preferably, the reflector can be obtained by etching into the active layer on either side of the waveguide.

This has the advantage that the reflector can be obtained without using additional regrowth steps.

Preferably, the reflector takes the form of a two-dimensional pattern. This allows efficient reflection, while allowing the reflector to be contained in a relatively short length of the device.

For a better understanding of the present invention, and to show how it may be put into effect, reference will now be made, by way of example, to the accompanying drawings, in which:-

Figure 1 is a plan view of a laser device in accordance with the invention.

Figure 2 is an enlarged schematic illustration of a region of Figure 1.

Figure 3 is a cross-sectional view through the device of Figure 1.

Figure 4 illustrates the room temperature (20°C) CW optical spectra at 60mA for (a) pre-etch non-AR coated and (b) post-etch AR coated conditions of the device of Figure 1.

Figure 5 illustrates the post-etch room temperature (20°C) CW L-I characteristics of the device of Figure 1.

Figure 6 illustrates the post-etch, room temperature (20°C) variation of lasing wavelength with CW bias current for the device of Figure 1.

Figure 1 is a top plan view of a laser device in accordance with the invention. The device 2 is an InGaAsP-InP laser, with a ridge-waveguide 4. The device consists of seven 0.8% compressively strained quantum wells, and operates at a centre wavelength of ~1.29μm. The laser is 350μm long, and acts as a Fabry-Perot (F-P) laser. It is cleaved on both end facets 6,8. The laser is bonded junction side up on a temperature-controlled submount (not shown) and the output can be connected via a lensed fibre. The back

facet 6 is AR coated to 0.1%, in order to suppress the F-P modes.

Figure 3 is a cross-sectional view, taken on line A-A in Figure 1. As shown in Figure 3, the device has an active region 10 within the structure, with a silicon dioxide layer 12, having a metal layer 14 above it as the uppermost layers. The central ridge-waveguide has a width W of, for example, approximately 3μm, with etched channels of width X of approximately 8μm on either side of the ridge waveguide.

In accordance with the preferred embodiment of the invention, a distributed reflector structure is provided on either side of the central ridge waveguide, leaving the waveguide itself untouched.

In this illustrated embodiment of the invention, the distributed reflectors take the form of an etched 2D-lattice grating 18. The grating 18 is etched into the bottom surfaces 20 of the channels 16, over a section of the cavity. This section has a length L of approximately 50μm, and is located towards the back facet 6 of the device, for example approximately 50μm from the back facet.

Figure 2 is an enlarged view of the etched grating pattern in one of the channels 16. The array comprises a series of holes 22, etched through the top contact 14 to a depth which is comparable to the depth of the active region 10. In this illustrated embodiment, the holes 22 are arranged in a hexagonal array. That is, each hole away from the edge of the array is surrounded by six equally spaced holes. This separation a is of the order of 0.60-0.65μm, and the holes have a radius r such that the radius-to-pitch ratio r:a is 0.17, although it may be in the range of 0.17-0.33.

The grating pattern could also be a square array, or any pattern which provides a suitable reflector.

Preferably, the holes are etched to a depth which

is very close to, or, more preferably, into the active region.

Advantageously, the holes can be obtained by post-processing using any available etching technique, for example, focused ion bean etching (FIBE)or reactive ion etching (RIE), without requiring any subsequent regrowth. This has the advantage that the device can be manufactured relatively simply and inexpensively.

This structure has the further advantage that the holes, which act as the reflectors, provide a high refractive index contrast ratio between the holes and the material of the device, of approximately 1:3.5.

In order to improve passivation, it is possible to fill in the etched holes with a suitable material, such as benzocyclobutene (BCB), which reduces this ratio to approximately 1.5:3.5. However, this ratio is sufficiently large that a highly selective characteristic can be obtained, over a short etched length.

The post-etch performance of the device is characterised in terms of the optical spectra. Measurements are taken at room temperature (20°C) under CW bias conditions. Figure 4a shows the pre-etch spectrum before AR coating at 60mA. This is indicative of a typical multi longitudinal mode F-P structure. Figure 4b illustrates clearly that, after etching, the device lases in a single longitudinal mode. Purely single mode operation is maintained over the entire operating current range up to over 3 times threshold. A typical SMSR value of >30dB is measured.

In order to investigate the stability of the lasting wavelength, the light current characteristics under CW bias conditions are measured at room temperature. Figure 5 shows a linear response above threshold, with no kinks evident, indicating that mode-hopping does not occur. A slope efficiency of 0.09 W/A

is measured along with an output power of greater than 2.5mW at twice threshold current. At room temperature, a reduction in threshold current of 2mA was observed as a result of the etch.

Single mode operation is further evidenced in Figure 6, which shows the variation of peak wavelength with CW bias current at room temperature (20°C). From threshold up to 85mA, the lasing wavelength is found to vary linearly at 0.009nm/mA, indicating mode-hop-free operation. The device spectra remain single mode over this range. Single mode emission is found to vary at the rate of 0.08nm/°C around room temperature.

One possible use of the device of the invention is in an integrated device which has, say, four such laser sources on a single device, with the distributed reflector structures of the four sources being different, such that the integrated device can selectively provide a source at any of four wavelengths.

There is thus described a technique which allows manufacture of a single-contact, mode-hop-free single longitudinal mode laser operating CW at room temperature, and bit rates up to approximately 10 GHz, to be produced from a previously multi-mode Fabry-Perot ridge-waveguide device.